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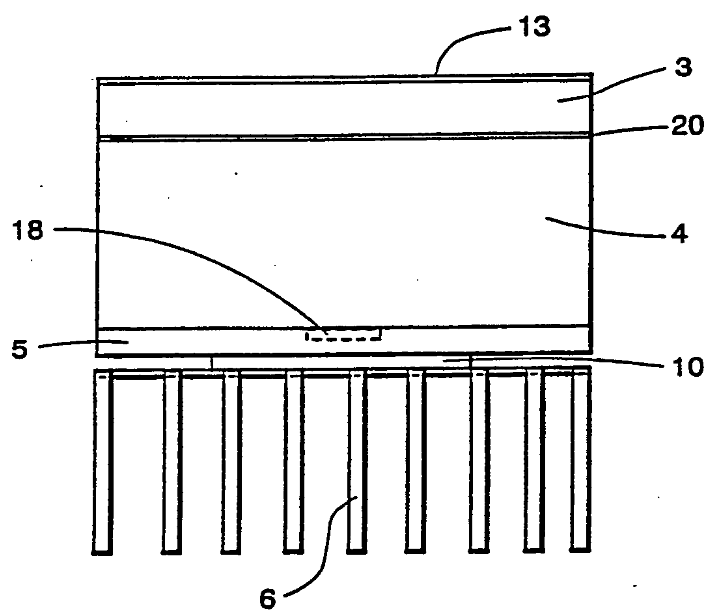
(54) Title: TEMPERATURE STABILIZATION BUFFER FOR A SOLID STATE ELECTRONIC COMPONENT



(57) Abstract

A thermal buffer (4) is introduced between a thermoelectric cooler (10) and a CCD array (3) in order to provide for uniform temperature distribution throughout the CCD array (3) to stabilize dark current.

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TEMPERATURE STABILIZATION BUFFER FOR A SOLID STATE ELECTRONIC COMPONENT

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to a solid-state device, such as a CCD, where the operating temperature is kept substantially constant to stabilize dark current noise.

2. Description of the Prior Art

When utilizing a solid-state imager to read an image scan, one of the main sources of noise that affects image quality is dark current. In a CCD array, dark current is the amount of ambient current detectable in individual imaging elements when the CCD is energized in the absence of the imaging beam. Typically to minimize the effects of this noise, the dark current in each element of the CCD array is measured prior to a scan and stored as an offset value for later correction of image readings. Technologists working with solid-state imagers wish that the problem of dark current noise were resolved so easily, unfortunately it is not.

In the process of scanning an imaging beam across a CCD array, the temperature of the array rises. Dark current noise is known to double for every 10°C or so increase in temperature. An increase in the dark current noise renders offset values determined prior to the scan insufficient to compensate for a growing adverse effect upon image signal resolution. Various attempts have been made to address the temperature-induced rise in dark current.

In U.S. patent 4,551,760, the inventor describes a method of cooling the CCD array to about +10°C to reduce dark current noise. He uses a thermoelectric cooler bonded to the rear surface of the CCD to maintain this low temperature and control the level of dark current attributable noise. However, while the dark current was reduced by the method, he found that condensate was apt to form on the glass face of the CCD interfering with an accurate reading of the image data. In order to avoid the condensate problem, others, who have cooled the CCD even lower, have sought to enclose the "cooled" CCD in a vacuum tight arrangement to minimize the possibility of humidity-induced condensate forming on its viewing surface. These solutions are both difficult and expensive to implement.

The present invention does not require significant cooling of the CCD. As it operates at near room temperature, it is much less susceptible to humidity problems. Consequently, it does not require the energy and expense of evacuating an enclosure and filling it with dry gas to keep the CCD cooled significantly below its operating environment. The present invention is a relatively inexpensive and easily-implementable solution to a well known problem of resolving the floating dark current problem for solid state devices.

SUMMARY OF THE INVENTION

This invention is based on two fundamental principles. First, it is often important that the temperature of a solid state electronic component, such as a CCD array, remain substantially constant during use. The dark current problem is largely related to the fact that the offset calibration values change while the CCD is in use. The apparatus of Applicant's invention

succ ssfully fixes th operating temperature of the CCD array to just below room temperatur so that the offset values remain a substantially accurate representation throughout image scanning and may be used to adjust the actual data. This approach has been successfully employed by Applicant in an industrial non-destructive testing radiographic system comprising scanner means, interactive display means, and storage and retrieval means.

Secondly, since this invention does not require cooling of the CCD to very low temperatures, it alleviates the time-consuming, costly and difficult measures that were heretofore undertaken to enclose and "refrigerate" the CCD. This invention provides good image signal resolution at near ambient air temperatures.

In an image detecting system comprising a CCD array and a cooling element used to control the temperature of said CCD array, wherein the improvement comprises:

a temperature buffering means interposed in thermal contact between said CCD array and said cooling element.

DESCRIPTION OF THE DRAWING

Figure 1 represents a prior art approach to cooling of a CCD array.

Figure 2 shows the invention.

Figure 3 is a schematic representation of circuitry employing the invention.

DETAILED DESCRIPTION OF THE INVENTION

In Figure 2, a heat transfer means 20 is thermally connected to the rear face of solid-state CCD imager 3, that is, opposite the face where the imaging beam is

receiv d. Heat transf r m ans 20 is utilized to provide a substantially uniform temperatur xchange from the rear face of the CCD 3 to heat buffering means 4. To be most effective, the heat transfer means 20, such as a thermal pad or thermally conductive glue, should remain in thermal contact with both heat buffering means 4 and CCD 3.

Heat buffering means 4 is comprised of a relatively highly thermally conductive material, such as aluminum or copper. It extends along the full length of CCD 3 and acts to integrate small temperature fluctuations along the CCD. A thermally conductive mounting plate 5 is centered and fixed orthogonal to heat buffering means 4. Thermistor 18 may be placed longitudinally into a grooved out section of mounting plate 5 such that the thermistor thermal contacts both heat buffering means 4 and mounting plate 5. Upon sensing a change in temperature of the heat buffering means, the thermistor's output, which is continuously compared with a reference temperature voltage, triggers the application of sufficient current to cooling element 10 to maintain the reference temperature. This feedback control is accomplished using standard servo amplifier and power control techniques which are well known in the art. See Figure 3.

Cooling element 10 is attached by means of a thermally conductive medium to mounting plate 5 on the side opposite heat buffering means 4. Cooling element 10 might typically be a thermoelectric cooler with the "cool" side fixed to mounting plate 5. The "hot" side of 10 is attached to heat sink 6 to vent away heat during temperature cooling and maintenance.

The prior art response to the variabl dark current problem can b found in figure 1. The emphasis is upon cooling th CCD array substantially below room temperature to about 10°C. A further definition of the dark current noise problem reveals that acceptable resolution of most signals can be obtained at about room temperature if that temperature can be sustained during imaging of the light source on the CCD. Unless the image signals are very small (e.g. astronomy signals), the key to relative freedom from temperature-dependent dark noise is to maintain a constant temperature so that the offset dark current values, established in the absence of light, will remain useful for making corrections to image data values.

The prior art solution (Fig. 1) bonds the thermoelectric cooling device (312, 314, and 316) directly to non-imaging side of the CCD (220). This solution may not be satisfactory in that the size of the cooling device may be smaller than the active area of the CCD array thus permitting uneven cooling. Further, the thermoelectric cooler (TE) itself is not a perfect device and due to manufacturing differences in its internal metallic junctions, there may be differences in temperature across its surface. Also, as heat from the "hot" side of the TE (312) is conducted to cap (214) and conducted away by thermally conductive braid 216, some heat can be transferred to flaps 212 which are bonded to the CCD (210). All of these sources provide an uneven distribution of temperatures across the CCD array and hence change the dark current noise from values measured during offset calibration.

The instant invention avoids the problem of improper sizing of TE 10 to the CCD by extending heat

transfer means and heat buffering means over the full length of the CCD. The heat buffering means smooths out changes in temperature so that: 1) no one element in the CCD array will experience any substantial difference in temperature from any other element along the array and, 2) any change in temperature will be slight and gradual. Heat buffering means 4 integrates temperature fluctuations and evenly distributes just-below-room temperature coolness of the TE as required. With the thermistor 18 being employed, it can respond to minute changes in temperature. Additionally, the operating temperature of the TE, e.g. 70°F, makes it unlikely that condensate or "dew" will form on imaging window 13 of the CCD. Thus, the substantially constant temperature during imaging of the CCD yields a substantially constant source of dark current noise which can be adequately compensated for through use of measured offset values during calibration.

It is understood that the specific components utilized above are for example purposes only for teaching the invention and are not intended to limit the invention. All suitable equivalents should be contemplated as being within the scope of the appended claims.

What is claimed is:

1. In a cooling system for controlling the level of dark current in a solid state electronic component, including a thermoelectric cooler and a temperature feedback control system, the improvement comprising:

a temperature buffering means, interposed between and in thermal contact with said solid state electronic component and said thermoelectric cooler, for maintaining a substantially uniform temperature throughout said solid state electronic component.

2. The apparatus recited in claim 1, wherein said temperature buffering means comprises a block of relatively highly thermally conductive material.

3. The apparatus recited in claim 2, wherein said buffering means is made of aluminum.

4. The apparatus recited in claim 2, wherein said buffering means is made of copper.

5. The apparatus recited in claim 1, wherein said solid state component comprises a CCD array.

6. In an image detecting system, comprising a CCD array and a cooling element used to control the temperature of said CCD array, the improvement comprising a temperature buffering means, interposed in thermal contact between said CCD array and said cooling element, for maintaining a substantially uniform temperature throughout the said CCD array.

7. In an industrial non-destructive testing reading and storage radiographic system comprising, in combination, scanner means, interactive display means, and storage and retrieval means, the improvement comprising:

said scanner means including a CCD array thermally coupled to a temperature buffer means interposed between said CCD array and a cooling means.

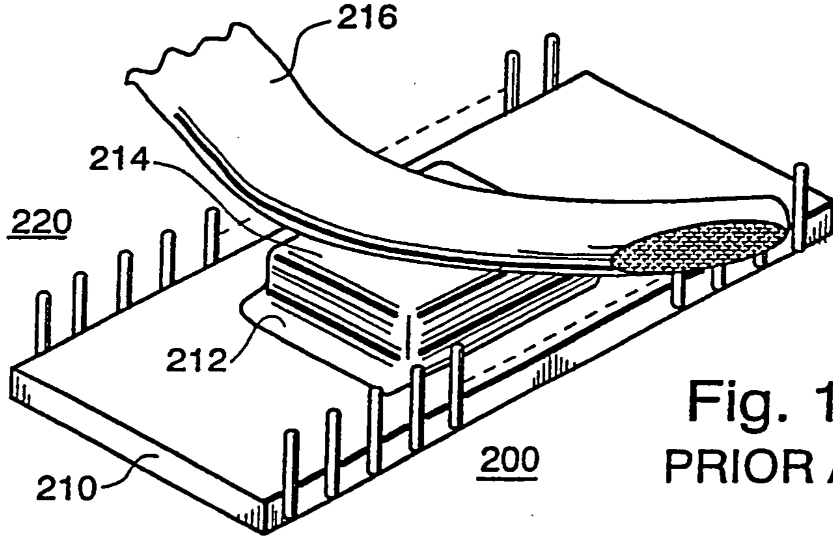

Fig. 1a
PRIOR ART

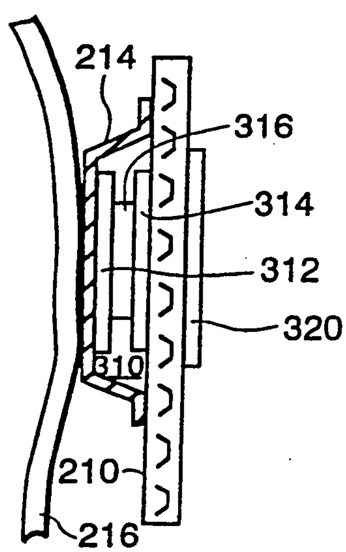

Fig. 1b
PRIOR ART

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Fig. 2

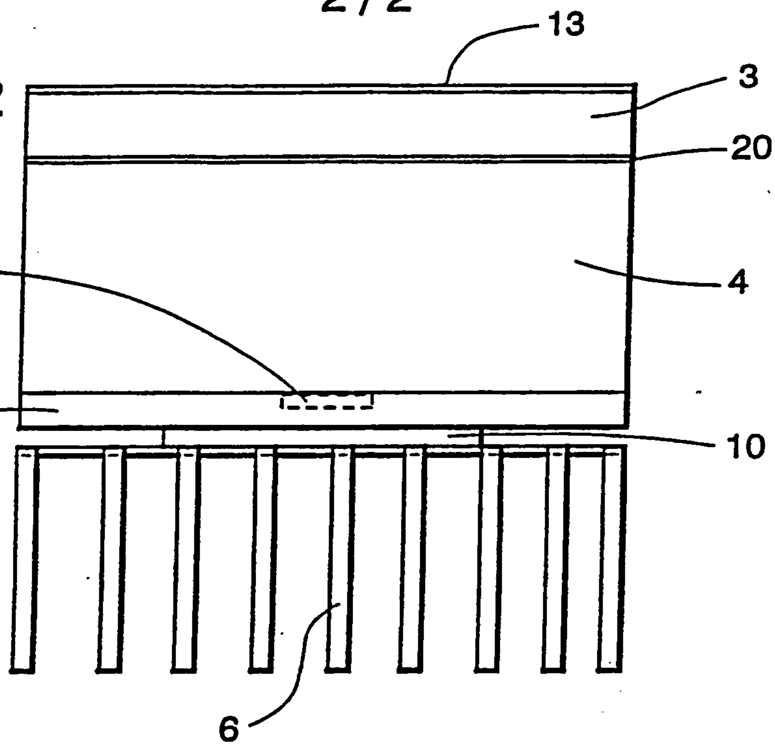
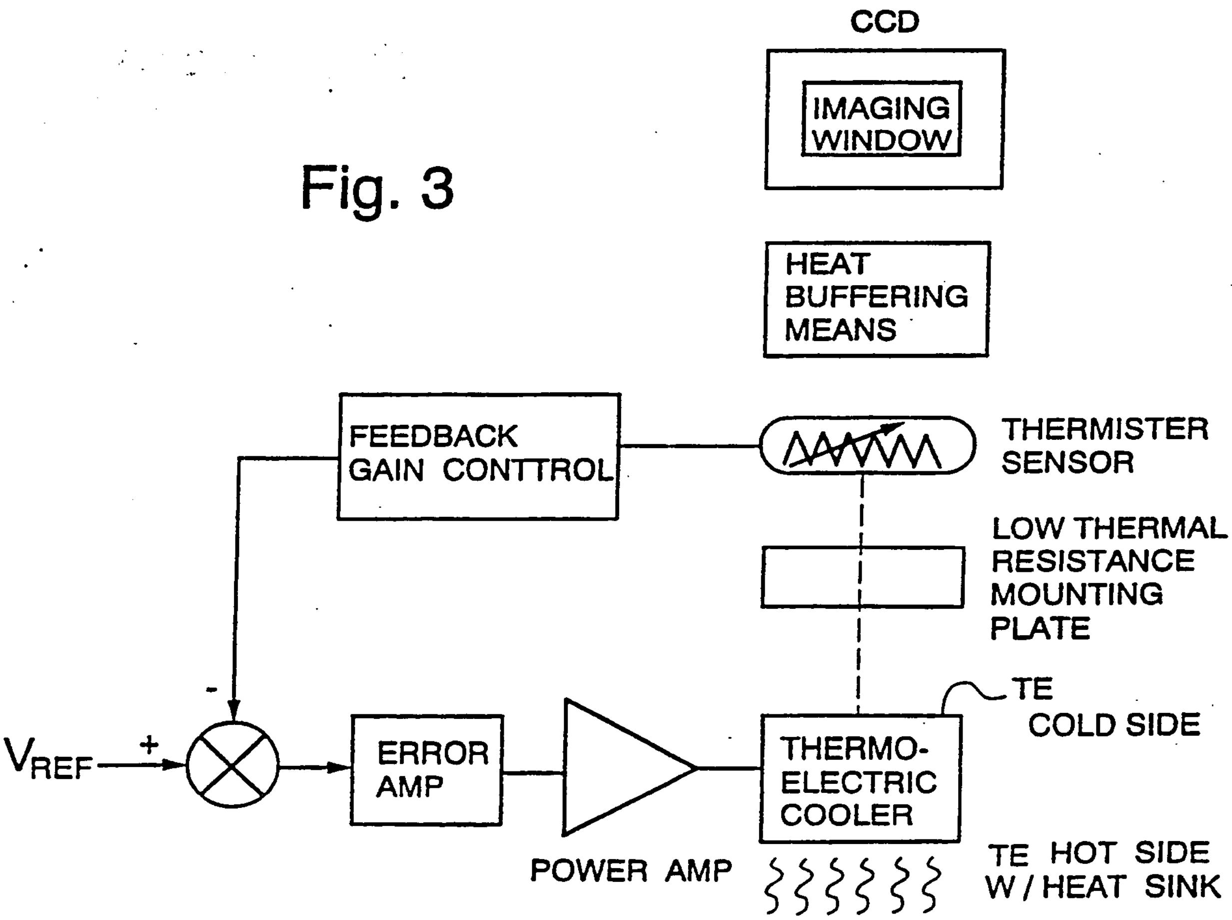

13
3
20
18
4
5
10
6

Fig. 3


CCD
IMAGING WINDOW
HEAT BUFFERING MEANS
FEEDBACK GAIN CONTTROL
THERMISTER SENSOR
LOW THERMAL RESISTANCE MOUNTING PLATE
TE COLD SIDE
V REF
+
-
ERROR AMP
THERMO-ELECTRIC COOLER
POWER AMP
TE HOT SIDE W / HEAT SINK

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INTERNATIONAL SEARCH REPORT

International Application No PCT/US91/07043

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): H04N 5/335, H04N 3/14
U.S.Cl.: 358/213.16,221 357/24LR

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	358/213.16,213.25,43,221 62/3.2,259.2 357/24LR 204/182.8

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X Y	US, A, 4,587,563 (BENDALL ET AL.) 06 May 1986 See col. 6, lines 63-68 and col. 7, lines 1-20.	1,5,6 7
Y	US, A, 4,551,760 (BENDELL) 05 November 1985 See col. 2, lines 37-53.	2-4
Y	US, A, 4,739,382 (BLOUKE ET AL.) 19 April 1988 See col. 2, lines 13-58.	1-7
A	US, A, 4,496,982 (LEVINE) 29 January 1985	1-7
A	US, A, 4,525,743 (WOOD, JR. ET AL.) 25 June 1985	1-7
A	US, A, 4,562,473 (LEVINE) 31 December 1985	1-7
A	US, A, 4,551,762 (LEVINE) 05 November 1985	1-7
A	US, A, 4,580,168 (LEVINE) 01 April 1986	1-7

* Special categories of cited documents: [15]
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
07 January 1992	30 JAN 1992
International Searching Authority [1]	Signature of Authorized Officer [20]
ISA/US	Glenton Burgess

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